Algal Community Habitat Preferences in Old Woman Creek Wetland, Erie County, Ohio

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Abstract. Algal communities were examined from May through August 1993 in Old Woman Creek National Estuarine Research Reserve and State Natural Area and Preserve, a shallow (<0.5 meter deep) 56 ha hypereutrophic wetland, located in Erie County along the south-central shore of Lake Erie. Most of the wetland is open water; the dominant macrophyte, *Nelumbo lutea*, covers about 30% of the surface area. Therefore, open water algae can be the primary autotroph contributing to the wetland's energy flow. Inflow regions are the primary collector of watershed agricultural runoff, and therefore have greater concentrations of nutrients than waters closer to Lake Erie. We did not find any difference in phytoplankon diversity between the sites near the inflow compared to sites closer to Lake Erie (the outflow). In general, half the biovolume of phytoplankton was composed of diatoms, and one-third euglenophytes. Average algal volumes of the back sites (9.01 x 10^6 µm^3/ml) were higher than the front sites (5.92 x 10^6 µm^3/ml). Periphyton diversity was slightly higher near the inflow. Periphyton growing on artificial substrate had about five times greater biovolume than phytoplankton; however, periphyton inverse Simpson diversity was about half of nearby phytoplankton. All sites were dominated by green algae and euglenophytes by number of individuals. Diatoms dominated under *Nelumbo lutea*; euglenophytes and small green algae dominated in turbid open-water regions. We suggest that light, the presence of aquatic vegetation, and hydrologic dynamics may be more important to determining the community structure in this wetland than nutrient concentrations or interspecific competition.

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INTRODUCTION

Coastal wetlands along the Laurentian Great Lakes have been subjected to a number of perturbations--including diking, drainage, introduction of exotic species, and increased pollution loading. These wetlands provide important functions, including ameliorating non-point pollution before it reaches the lakes. Algae are an important component of this nutrient removal and transformation (Reeder 1994). Current research on Great Lakes coastal wetlands use a variety of biological indicators to assess wetland ecosystem health, including primary producer communities (Brazner and others 2007) and benthic, periphytic and phytoplanktonic algal biomass (McNair and Chow-Frazier 2003). At one of the more studied coastal wetlands along lake Erie, Old Woman Creek National Estuarine Research Reserve and State Natural Area and Preserve (Old Woman Creek), there is spatial variability in the distribution of non-point pollution: areas near the inflow stream have higher maximum nutrient concentrations and pesticides than the outflow into Lake Erie (Heath 1987; Krieger 2003; Mitsch and Reeder 1992). The nutrient runoff is due mostly to agricultural practices and increased erosion within the watershed (Evans and Seamon 1997; Reeder and Eisner 1994).

Nutrient processing in Old Woman Creek is primarily (Mitsch and Reeder 1991; Reeder 1994), or to a large percentage (Francko and Whyte 1999) performed by algae. Casamata and others (1999) found algal communities in wetlands within impacted and unimpacted watersheds in Ohio were not discernibly different; however, they only sampled each wetland once, which may have been inadequate to determine patterns. Old Woman Creek's morphology makes it an excellent field model to observe the algal communities subjected to a variety of nutrient and light conditions. Accordingly, we investigated algal community structure in Old Woman Creek over a four-month period. In addition, we examined if communities associated with the dominant macrophyte, *Nelumbo lutea* (Willd.) Pers. (American lotus), differed from those found in open water.

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MATERIALS AND METHODS

Site Description

Old Woman Creek is a 56 ha wetland on the southern edge of Lake Erie's western basin near Huron, Ohio, U.S.A. (Fig. 1). Depths in the wetland average about 0.5 m or less, but this can change dramatically (up to 1 m) throughout the year--not only because of storm surges from the watershed, but also because of adjacent lake level fluctuations. A barrier beach, which may be opened or closed by hydrologic events, also has profound effects on the wetland's hydroperiod (*c.f.* Mitsch and Reeder 1992). During our study, less than 30 percent of the wetland was covered by the dominant macrophyte, *Nelumbo lutea*; therefore, the system was dominated by open water primary producers. However, under certain conditions submersed and emergent vascular vegetation can become more prevalent (Francko and Whyte 1999).

To study the effect of non-point pollution on the community structure of the phytoplankton, we selected two sites in the "front" (near Lake Erie), which tends to have lower nutrient concentrations and two near the "rear" of the wetland, which tend to accumulate non-point pollution. One site in each zone was in open water habitat; the other was in a bed of *Nelumbo lutea*. The rear sites are separated from the front of the wetland by a railroad bed--effectively dividing the wetland into two distinct basins. The railroad bridge often acts as a restriction to hold water and suspended sediments in the upper estuary. The front sites are near the wetland barrier beach in the lower estuary near the outflow to Lake Erie and tend to have lower nutrient and suspended sediment concentrations (Mitsch and Reeder 1992). All sites had similar depths (depth varied throughout the study period from about 0.3 to 1.3 meters).

Field and Laboratory Methods

Samples of water and phytoplankton were collected every two weeks from May-August 1993. To sample the phytoplankton at each site, 500 ml subsamples of Old Woman Creek water were collected with a five liter Van Dorn sampler. Algae were fixed with Lugol's Iodine, and allowed to settle in 500 ml graduated cylinders. The algae-free water from the cylinders was evacuated by siphoning from the top, being cautious not to disturb the settled algae. The resulting algal slurry (50 ml) was homogenized and two subsamples of known volume (usually 50µl) were mounted on slides for identification and enumeration.

Periphyton samples were collected on artificial substrate samplers (Wildlife Supply Co., Model 156-A10). Floating periphyton samplers were suspended in the water column for at least three weeks. One slide was randomly removed from a sampler at each sampling date and immediately placed in 10 percent ethyl alcohol. Periphyton were removed with a razor blade and a slurry of a known volume was prepared for microscopic analysis (APHA 1985).

Algae were identified and enumerated using a Nikon light microscope with Hoffman Modulation Contrast, generally at 630X. Species determinations were made using keys by Prescott (1982), Tiffany and Britton (1952), and Tiffany (1934). To estimate algal volume, measurements were made on at least 12 representative taxa, when possible, and compared to equivalent geometric shapes to calculate the average species volume (Wetzel and Likens 2000). Because the artificial substrate favors the collection of certain species, we calculated an inverted Simpson's dominance index (d_s) for the periphyton communities.

Nutrient measurements included total phosphorus (TP) and soluble reactive phosphorus (SRP), nitrate (NO3), nitrite (NO_2), and ammonia (NH_3). SRP was determined as molybdate reactive phosphorus (Murphy and Riley 1962). TP was determined as orthophosphate released after digestion with ammonium persulfate (APHA 1985). Ammonium was analyzed using the phenate method (Weatherburn 1967). Nitrate and nitrite nitrogen species were determined by passing the samples through a cadmium reduction column and determining the final nitrite concentrations using the sulfanilamide method (APHA 1985).

Differences between mean nutrient concentrations and biovolume at each of the four sites were compared with ANOVA (Zar 1984). Although diversity indicies calculated for each site were easily compared by inspection, we calculated phytoplankton Shannon diversity indicies and variance for each site, and used a modified ANOVA procedure to compare between Shannon indicies (Zar 1984). Likewise, we assessed if the mean inverse Simpson community diversity from the front was the same as in the back using a modified Student's *t*-test (Zar 1984).

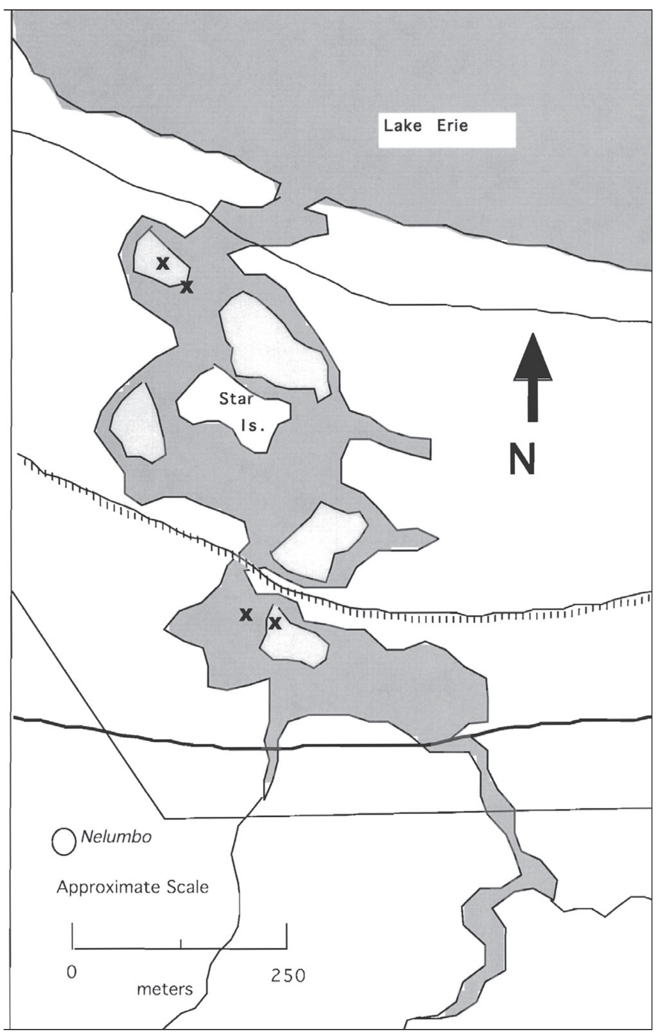

Figure 1. Old Woman Creek wetland, Erie County, Ohio, showing sampling stations (X).

RESULTS

Because the sites were not more than 50 meters from each other; it was not surprising that there was not a significant difference between nutrient concentrations in *Nelumbo lutea* compared to those found in the open water at the same end of the wetland. Nutrients in the wetland were typically higher in the back sites than the front sites due to non-point loading (Table 1); however, only TP and SRP were statistically higher in back (ANOVA, $p<0.05$). Although nitrogen concentrations between sites were not statistically different (ANOVA, $p>0.05$), they are probably ecologically significant: the ratio of dissolved N:P was around 6:1 in the front sites, and above 11:1 in the back sites.

The phytoplankton volume was the greatest during August, when production was generally lower than in June and July (Figure 2). Algal volumes of the back sites (9.013×10^6 µm^3/ml) were significantly higher than the front sites (5.916×10^6 µm^3/ml);

Table 1

Mean [µg/1(SD)] nutrient concentrations, chorophyll, algal volume and diversity in Old Woman Creek wetland during the growing season.

	Front Sites		Back Sites	
	Nelumbo	Open Water	Nelumbo	Open Water
Nutrients				
Soluble Reactive P	26 (13)	28 (16)	26 (12)	26 (13)
Total P	83 (30)	81 (35)	105 (34)	103 (31)
Nitrate N	30 (25)	50 (43)	105 (181)	155 (249)
Nitrite N	23 (21)	22 (19)	43 (47)	57 (51)
Ammonium N	115 (58)	114 (65)	127 (91)	156 (83)
Phytoplankton				
Chlorophyll *a*	144 (50)	90 (72)	125 (83)	126 (86)
Volume (10^6 µm^3/ml)	6.90 (2.30)	5.00 (3.18)	9.25 (4.23)	8.7 (3.3)
Inverse Simpson's Diversity	11.06	12.41	13.8	13.4
Periphyton				
Volume (10^6 µm^3/ml)	38.1 (28.4)		47.3 (21.6)	
Inverse Simpson's Diversity	5.95		7.3	

however there were no significant differences within macrophytes versus the open water. Front sites were dominated by diatoms nearly exclusively; however, euglenophytes and small green algae are also important contributors to the community volume. The back sites were dominated mutually by diatoms and euglenophytes, with other algal groups making less of a contribution to total community volume. Sites located within a macrophyte bed tended to be dominated by euglenophytes in early June and by diatoms at the other times in the growing season, whereas those in open water are dominated by diatoms early in the year and euglenophytes in late July (Fig. 2).

All periphyton communities were dominated by diatoms--which composed 48 percent of the community volume, with green algae (30 percent) and euglenophytes (18 percent) also making large contributions to the community volume. The back sites, with typically higher nutrients than the front sites, were dominated also by diatoms (42 percent); however green algae (37 percent) made a greater contribution to the community volume than in the front. The front sites were dominated by diatoms (55 percent) with green algae (23 percent) and euglenophytes (19 percent).

We observed 63 species of algae (Table 2). Many species appeared at nearly all sites throughout the sampling period. Species found in more than half of all plankton samples included *Akistrodesmus convulutus*, *A. falcatus*, *Lagerheimia quadriseta*, *Scenedsmus quadricauda*, *Schroederia setigera*, *Cyclotella meneghheniana*, *Diploneis puella*, *Melosira distans*, *Navicula mutica*, *Nitzschia acicularis* (this was the only species found in every sample), *Merismopedia tenuissima*, and *Phacus caudatus*. Only *Scenedesmus denticulatus* showed a preference for higher nutrient concentrations in the back sites. *Tetaedron quadratum*, *Micractinium pusillum*, and *Treubaria setigerum* preferred sites near the lake. Seventy-two percent of the planktonic species were also found on the periphyton samplers; only 12 percent showed any preference for either open water or *Nelumbo* beds.

Common chlorophytes included *Ankistrodesmus* sp., *Lagerheimia* sp., and *Scenedesmus* sp. Other common genera included *Cryptomonas erosa*, and diatoms, such as *Cyclotella meneghheniana*, *Diploneis* sp., *Melosira* (=*Aulacoseira*) sp., *Navicula* sp., and *Nitzschia* sp. Some species were typically located at the front sites, such as *Treubaria setigera*, however, patterns were not well-defined.

We observed 46 species of periphyton on artificial substrate (glass microscope slides). Of these, 36 were also found planktonic. Periphyton not found in the open water were *Scenedesmus abundans*, *Oedogonium* sp., *Achnanthes* sp., *Cymbella* sp., *Fragilaria* sp, *Meridion* sp., *Stauroneis* sp., *Terpsinoe* sp., *Oscillatoria* sp., and *Phacus pleuronectes*.

Diatoms and chlorophytes were dominant members of the periphyton throughout the study period. Species found in 75 percent or more of the samples were *Ankistrodesmus faculatus*, *Scenedesumus quadricauda*, *Cyclotella meneghheniana*, *Fragilaria* sp., *Melosira distans*, *Navicula muticata*, *Nitzchia acicularis*, and

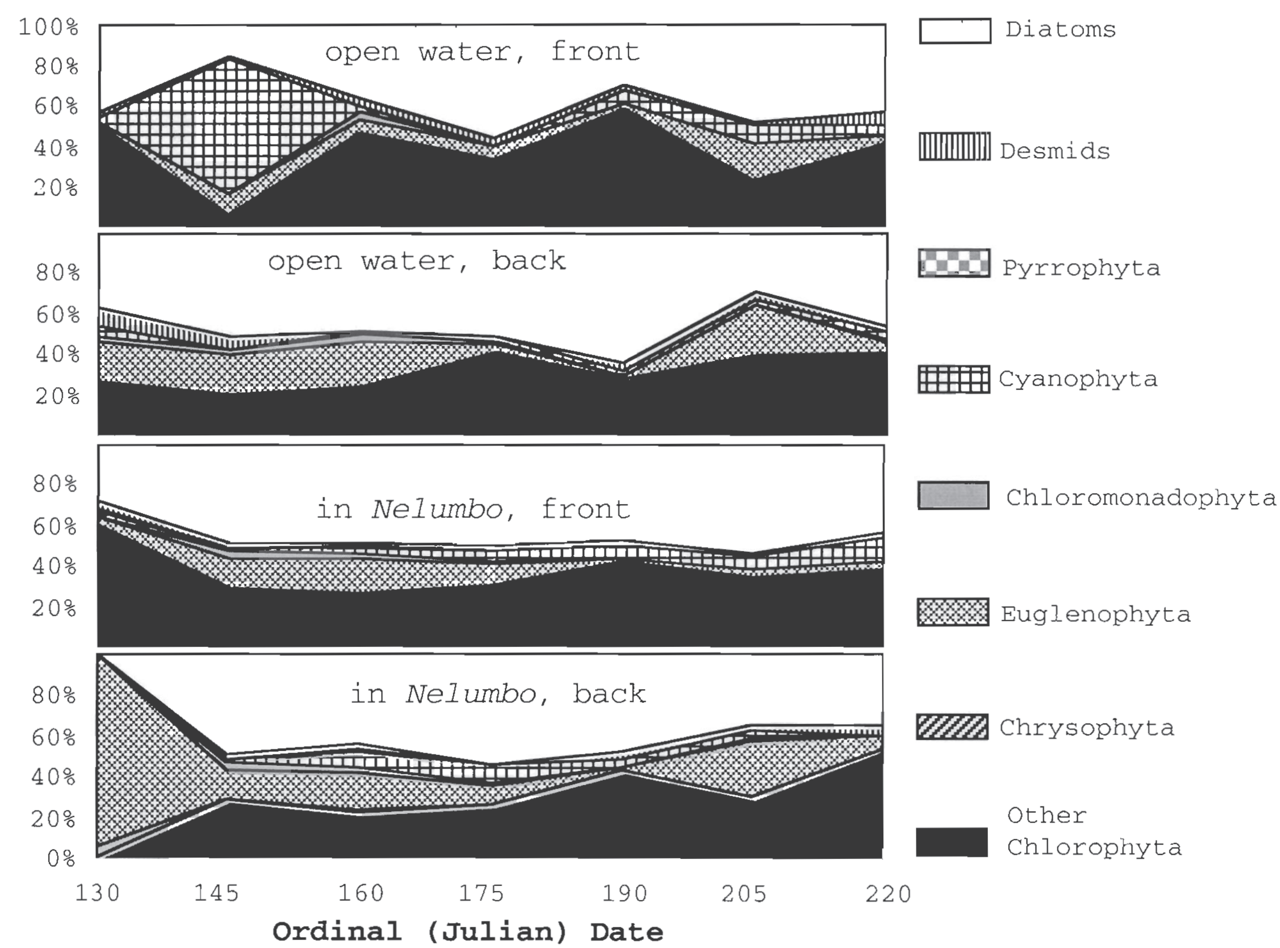

FIGURE 2. Seasonal changes in the percentage of algae in water samples taken closer to Lake Erie (front) and sites more impacted by nonpoint pollution from the watershed (back) both within vegetation (*Nelumbo*) and in the open water.

Table 2

Algae found (percent occurence in samples for each site) in Old Woman Creek wetland

Phylum	Genus or Species	Authority	Front of Wetland		Back of Wetland		Periphyton	
			Open Water	Nelumbo	Open Water	Nelumbo	Front	Back
Cryptophyta	*Cryptomonas erosa*	Ehrenberg	43	57	71	57		50
Chlorophyta	*Actinastrum hantzchii*	Lagerheim	57	57	29	57		
Chlorophyta	*Ankistrodesmus convulutus*	Corda	86	100	86	71		
Chlorophyta	*Ankistrodesmus falcatus*	(Corda) Ralfs	86	100	100	100	83	100
Chlorophyta	*Characium ambiguum*	Hermann	29		14	14		
Chlorophyta	*Chlorella vulgaris*	Beijerinck	29	29		29		
Chlorophyta	*Crucigenia fenestrata*	(Schmidle) Schmidle	29	14		29		
Chlorophyta	*Crucigenia quadrata*	Morren	29	14	14	29		
Chlorophyta	*Crucigenia tetrapedia*	(Kirch.) West and West	29	29	29	43	17	50
Chlorophyta	*Franceia droescheri*	(Lemm.) G.M. Smith	14	14	14	14		
Chlorophyta	*Kirchneriella subsolitaria*	G.S. West	29	43	43	57	33	17
Chlorophyta	*Lagerheimia quadriseta*	(Lemm.) G.M. Smith	57	71	100	57	17	17
Chlorophyta	*Lagerheimia wratislaviensis*	Schroder	29	29	57	57		
Chlorophyta	*Micractinium pusillum*	Fresenius	71	14	14	29	67	67
Chlorophyta	*Pediastrum duplex*	Meyen	14	43	43	29		33
Chlorophyta	*Scenedesmus abundans*	(Kirch.) Chodat					17	0
Chlorophyta	*S. bijuga*	(Turp.) Lagerheim	43	29	29	57	33	0
Chlorophyta	*S. denticulatus*	Lagerheim			14	14	17	0
Chlorophyta	*S. dimorphus*	(Turp.) Kuetzing	29	29	29	14	33	33
Chlorophyta	*S. opoliensis*	P. Richter	29	14	14	14	17	0
Chlorophyta	*S. quadricauda*	(Turp.) de Brebisson	86	86	100	100	100	83
Chlorophyta	*Schroederia setigera*	(Schroder) Lemmermann	86	86	100	100	33	17
Chlorophyta	*Tetraedron quadratum*	(Reinsch) Hansgirg	14				17	
Chlorophyta	*T. regulare*	Kuetzing	43	57	43	57		
Chlorophyta	*Tetrastrum glabrum*	(Roll) Ahlstrom and Tiffany	29	43	43	71	0	17
Chlorophyta	*T. heteracanthum*	(Nordstedt) Chodat	0	29	14	0		
Chlorophyta	*Oedogonium* sp.	Link					33	50
Chlorophyta	*Treubaria setigerum*	(Archer) G.M. Smith	14	57	14			
Chlorophyta	*Gloeocystis ampla*	Playfair	29	29	29	43	17	0
Chlorophyta	*Chlamydomonas globosa*	J. Snow	86	29	57	43	33	0
Charophyta	*Closterium acerosum*	(Schrank) Ehrenberg ex Ralfs	86	57	57	71	0	33
Charophyta	*Cosmarium biretum*	Playfair	71	57	71	71	50	83

Table 2 (cont.)

Algae found (percent occurence in samples for each site) in Old Woman Creek wetland

Phylum	Genus or Species	Authority	Front of Wetland		Back of Wetland		Periphyton	
			Open Water	Nelumbo	Open Water	Nelumbo	Front	Back
Heterokontophyta	*Dinobryon divergens*	O.E. Imhof	29	43	14	29		
Bacillariophyta	*Achnanthes* sp.	Bory de Saint-Vincent					50	
Bacillariophyta	*Cyclotella meneghiniana*	Kutzing	86	86	86	86	100	100
Bacillariophyta	*Cymbella* sp.	C. Agardh					50	50
Bacillariophyta	*Diploneis puella*	(Schumann) Cleve	86	100	100	100	67	83
Bacillariophyta	*Fragilaria* sp.	Lyngbye					100	100
Bacillariophyta	*Gomphonema* sp.	Ehrenberg	43	29	43	57	67	83
Bacillariophyta	*Melosira distans*	(Ehrenberg) Kutz	100	100	86	100	83	100
Bacillariophyta	*Melosira granulata*	(Ehrenberg) Ralfs	29	29	57	0	50	50
Bacillariophyta	*Meridion* sp.	C. Agardh					33	33
Bacillariophyta	*Navicula mutica*	Kutzing	86	100	100	100	100	100
Bacillariophyta	*Nitzschia acicularis*	(Kutzing) W. Smith	100	100	100	100	100	100
Bacillariophyta	*Rhoicosphenia* sp.	Grunow	14	0	14	14	67	100
Bacillariophyta	*Stauroneis* sp.	Ehrenberg					17	17
Bacillariophyta	*Terpsinoe* sp.	Ehrenberg					17	0
Cyanobacteria	*Aphanocapsa rivularis*	(Charmicheal) Rabenhorst	14	29	29	14		
Cyanobacteria	*Merismopedia tenuissima*	Lemmermann	86	100	86	71	17	33
Cyanobacteria	*Oscillatoria* sp.	Vaucher ex Gomont					100	100
Cyanobacteria	*Phormidium tenue*	(Meneghini) Gomont	29	29	14	57	50	50
Cyanobacteria	*Spirulina nordstedii*	Gomont	29	29	14	29		
Euglenozoa	*Euglena acus*	Ehrenberg	43	43	86	71	17	17
Euglenozoa	*E. convoluta*	Korshikov	29	43	86	100	17	0
Euglenozoa	*E. gracilis*	Klebs	29	71	57	71	33	33
Euglenozoa	*E. minuta*	Prescott	29	14	29	29	33	17
Euglenozoa	*Phacus caudatus*	Hubner	86	86	86	86	0	33
Euglenozoa	*P. longicauda*	(Ehrenberg) Dujardin	14	57	43	29		
Euglenozoa	*P. pleuronectes*	(O.F. Muller) Dujardin					50	83
Euglenozoa	*Trachelomonas armata*	(Ehrenberg) F. Stein	14	14	43	14	0	17
Euglenozoa	*T. playfairii*	Deflandre	14	0	14	14		
Euglenozoa	*T. volvocina*	Ehrenberg	43	29	29	43	17	0
Myzozoa	*Glenodinium pulvisculus*	(Ehrenberg) F. Stein	14	29	0	29		

Oscillatoria sp. Species normally found in the back sites higher nutrient concentrations included *Cryptomonas erosa*, *Crucigenia tetrapedia*, *Pediastrum duplex*, *Closterium acerosum*, *Phacus caudatus*, and *Trachelomonas armata*. Periphyton which were more likely to be located in near the mouth of the wetland (lower nutrient concentrations) were *Scenedesmus abundans*, *S. bijuga*, *S. opoliensis*, *Tetradron quadratum*, *Gleocystis ampla*, *Chlamydomonas globosa*, *Achnanthes* sp., *Terpsinoe* sp. *Phormidium tenue*, *Euglena convoluta*, and *Trachelomonas volvocina*.

Thirty-seven percent of the periphyton species had a site preference; whereas only eight percent of the plankton algae were more or less associated with sites upstream of the railroad bridge. Shannon diversity of the phytoplankton communities was highest in the back sites (H'=2.80 back v. 2.65 in the front), and the sites in the macrophyte beds (H' 2.79 back v. 2.65 in the open water); however, there was no significant difference in diversity indices between any sites. There was no seasonal trend to phytoplankton diversity. Periphyton diversity was the highest during June when the periphyton density was also the greatest. Diversity indices indicated that periphyton diversity was highest at the back sites (d_s = 7.29 back v. 5.95 in the front); but this was not consistent throughout the season.

DISCUSSION

Seasonal Trends

There are few well-defined successional species replacements in the phytoplankton communities at Old Woman Creek. This may be due to sediment perturbation, either by wind and water, or biotic action (Havens, 1991; Klarer and Millie, 1994). Algal communities at Old Woman Creek have a bimodal seasonality (Klarer and Millie 1992). This is common in phytoplankton of temperate wetlands (Vymazal 1995). During 1993, our algal numbers exhibit this bimodal trend, however, the peak in early May is quite large--1.81 x 10^9 cells l^{-1}, which is larger than the May blooms reported by Klarer and Millie (1992). The high volume during the 1993 vernal peak was largely due to euglenophytes. The autumnal peak, which actually begins in late July and early August, is of similar magnitude to that reported by Klarer and Millie (1992)--having 2.8 x10^7 cells l^{-1}.

Algal volumes, however, do not show the same bimodal seasonality as algal numbers. They have a small peak in May, followed by a much larger peak in late July and early August. This is somewhat related to algal numbers; however, we see temporal differences in communities. The early peak is dominated by small euglenophytes; whereas the late summer peak is dominated by the much larger diatoms--producing higher total community algal volumes.

Despite the extended sampling, we were not able to determine any statistically significant differences in algal communities. The high variability may make algae poor indicators of environmental perturbations in these systems. This is similar to the problem that Casamatta and others (1999) found when they examined Ohio wetlands. However, in sharp contrast to Casamatta and others, who found that Cyanobacteria and Cryptopytes dominated, we, like Klarer and Millie (1992), found that diatoms and Euglenophytes dominate at Old Woman Creek. This may be due to other ecological factors that were not prevalent at the wetlands that Casamatta and others (1999) examined.

McNair and Chow-Fraser (2003) examined peak growing season biomass of phytoplankton, periphyton, and benthic algae in 24 Great Lakes coastal wetlands, including Old Woman Creek. Their statistical analysis grouping wetlands by physiochemical environmental variables suggested Old Woman Creek was a consistent outlier. Old Woman Creek's periphyton and phytoplankton chlorophyll concentrations (usually over 150 µg l^{-1} for periphyton, and phytoplankton generally >100µg l^{-1}) far exceeded those found in the other wetlands (around 20 µg l^{-1} in periphyton and usually around 10 µg l^{-1} for phytoplankton).

Nutrients

McNair and Chow Fraser (2003) suggested Old Woman Creek wetland's high phosphorus and low water clarity contributed to the high primary productivity. Nutrient loading is generally considered the primary factor that may affect community structure in aquatic ecosystems (Wetzel 2003) including wetlands (Pan and Stevenson 1996, Pan and others 2000, Ortega-Mayagoitra 2003, Zimmer and others 2003, Brazner and others 2007). Algal communities are known to change in response to different macronutrient ratios (Kilham, 1971; Kilham and Kilham 1978; Smith, 1983). The high phosphorus loading and high algal productivity would cause most limnologists to classify this water body as hypereutrophic (Wetzel 2001). However, it is interesting to note that unlike eutrophic lakes, which generally have blue-green algae blooms, low oxygen levels, and low diversity (Wetzel, 2001) this wetland is dominated by green algae and diatoms, moderate oxygen levels (with profound daily fluctuations (Reeder and Binion 2001, Cornell and Klarer 2008), and high diversity. This wetland, as well as many others, may not conform to limnologically derived definitions of trophic status.

Even with extraordinary primary production, we did not see any biotically induced nutrient depletion. This is consistent with the findings of Heath (1985), who did not find evidence of phosphorus limitation in Old Woman Creek. Green algae and diatoms were usually dominant--suggesting that neither nitrogen (a high N:P in the case of green algae) nor silicates (a high Si:P in the case of diatoms) are ever in relatively limiting concentrations during the growing season.

Nutrient concentrations are not effected by the presence of macrophytes. This is not surprising due to the closeness of the sites, and wind mixing. This is not to suggest that biotically or chemically induced nutrient exchange from the sediments are not important or do not occur, it is just not the most significant factor regulating nutrient concentrations between sites in versus out of macrophyte beds.

Given the marked differences in nutrient concentrations, especially dissolved inorganic nitrogen, between the front and back of the wetland (Table 1), we expected to see more profound differences in the algal diversity at each site. This did not hold true for phytoplankton nor epiphytes. Diversity was not markedly different, and most of the algal species were found at both sites. However, there were changes in the community as the season progressed and as the *Nelumbo lutea* beds expanded to cover large areas of the open water.

The nutrient loading at the back sites appears to affect phytoplankton community algal volume more than community structure. This could have important ecological consequences, since algal volumes are more closely related to primary production than algal numbers (Reeder and Binion, 2001). The back sites had higher periphyton volumes, indicating that periphyton would be more important contributors to primary production in higher nutrient conditions. In the back sites, green algae composed a larger percentage of the community periphyton than at the front sites.

Light Limitations

Whether the community is located in the front or back of the wetland (nutrient loading) is not as important to community structure as the presence of macrophytes. The macrophytes tend to change the community structure (although not the diversity). We suggest this is due to reduced light penetration. The dominant macrophyte, *Nelumbo lutea*, probably has little effect on the community structure (e.g. shading) until at least the middle of June, when the aerial leaves appear. At this time we see the sites in the macrophyte beds shift from an euglenophyte to diatom dominated community. This is not a common trend. Algal communities in eutrophic and hypereutrophic systems—which tend to shift from diatom dominated systems to some other group, such as green or blue-green algae (Reynolds 1984). Old Woman Creek maintains a high enough N:P ratio that a secondary nitrogen limitation does not occur--which tend to favor blue-green algae for their nitrogen fixing abilities (Smith 1983). The soluble inorganic N:P ratio was always above 6:1 in the front sites, and above 11:1 in the back.

As the season progresses, in the periphyton in the macrophyte beds, community dominance shifts from euglenophyte to diatoms. The open water communities, at nearly the same time, shift from a diatom to a euglenophyte-dominated community--as would be considered a typical seasonal community succession (Reynolds 1984). Therefore, the *Nelumbo* appears to provide some competitive advantage for the diatoms over the euglenophytes, possibly due to shading, or providing substrate for attachment.

The hypothesis that shading is important would help determine how turbidity affects community structure. Mitsch and Reeder (1990) suggested that resuspended nutrients in Old Woman Creek might be important contributors of P to the water, thus enhancing productivity. Havens (1991) demonstrated that biotically-induced sediment resuspension in Old Woman Creek created a kind of early successional stage community, composed largely of *r*-strategists. Our more hydrologically active sites in the back did seem to conform to Haven's suggestion of dominance by small green algae; however, we also found more large diatoms in the areas with low light (in *Nelumbo*). Krieger and Klarer (1991) discussed one possible way this could occur. They found that sediment resuspension in Old Woman Creek can also suspend large benthic diatoms into the plankton. It seems that muddy water appears to favor euglenophytes and small green algae; whereas similar low-light situations in beds of *Nelumbo* favor diatoms. Ortega-Mayagoitia and others (2003) found sediment resuspension in a central Spain wetland increased nutrients and resulted in a more diverse phytoplankton community.

Although nutrients and competition are usually thought of as important components determining biodiversity and growth in algal communities, we find this may not be the case at Old Woman Creek. The wetland may be somewhat nutrient limited at times (Heath 1985), however, this may not be the most important limitation. The peak nutrient input is in late May and early June; however, production in Old Woman Creek usually peaks in July (Reeder 1994, Reeder and Binion 2001), when nutrients concentrations are much lower than the maximum values. Perhaps non-point runoff brings in copious amounts of herbicides and pesticides, causing declines in community volumes--especially at sites nearer the "source" of the non-point pollution. However, algal volume is significantly higher at the back sites, where presumably higher pesticide loading should be. It appears that sunlight restriction, either by *Nelumbo* shading or turbidity, may be an important limiting factor. It can explain the community structure shifts we and other researchers have seen in Old Woman Creek.

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